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National Eutrophication Survey, Corvallis, Oreg

Prepared for

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REPORT

ON

MEDINA LAKE

BANDERA AND MEDINA COUNTIES

TEXAS

EPA REGION VI

WORKING PAPER NO. 652

WITH THE COOPERATION OF THE

TEXAS WATER QUALITY BOARD

AND THE

TEXAS NATIONAL GUARD

FEBRUARY, 1977

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGEMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Texas Water Quality Board for professional involvement, to the Texas National Guard for conducting the tributary sampling phase of the Survey, and to those Texas wastewater treatment plant operators who voluntarily provided effluent samples.

Hugh C. Yantis, Jr., Executive Director of the Texas Water Quality Board, and John B. Latchford, Jr., Director, and the staff of the Field Operations Division provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General Thomas Bishop, the Adjutant General of Texas, and Project Officer Colonel William L. Seals, who directed the volunteer efforts of the Texas National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

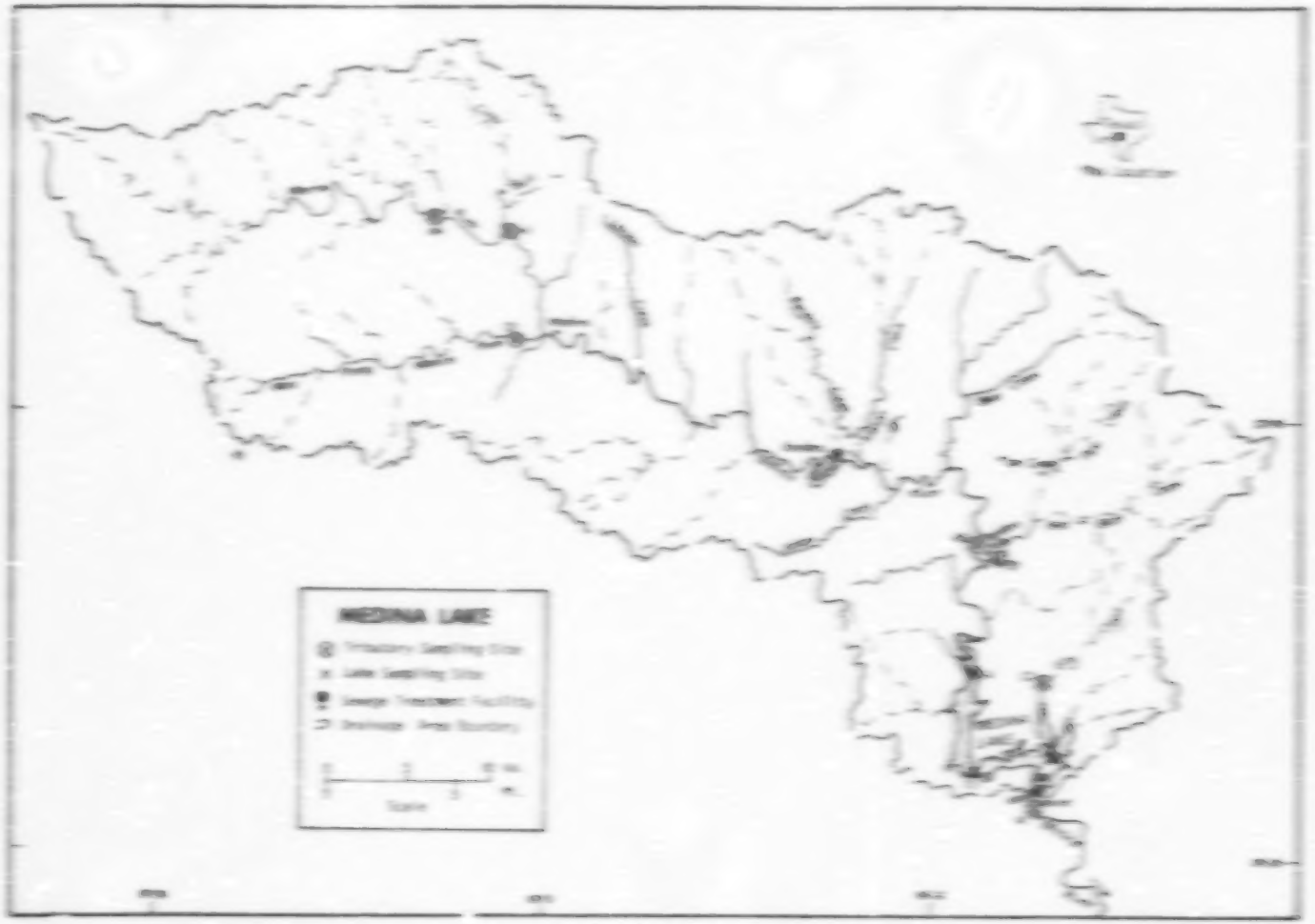
NATIONAL EUTROPHICATION SURVEY

STUDY RESERVOIRS

State of Texas

NAME	COUNTY
Amistad	Val Verde
Bastrop	Bastrop
Belton	Bell, Coryell
Braunig	Bexar
Brownwood	Brown
Buchanan	Burnet, Llano
Caddo	Harrison, Marion, TX; Caddo Parish, LA
Calaveras	Bexar
Canyon	Comal
Colorado City	Mitchell
Corpus Christi	Jim Wells, Live Oak, San Patricio
Diversion	Archer, Baylor
Eagle Mountain	Tarrant, Wise
Fort Phantom Hill	Jones
Houston	Harris
Kemp	Baylor
Lake O'The Pines	Camp, Marion, Morris, Upshur
Lavon	Collin
Lewisville (Garza-Little Elm)	Denton
Livingston	Polk, San Jacinto, Trinity, Walker

Lynden B. Johnson	Burnet, Llano
Medina	Randers, Medina
Meredith	Hutchinson, Moore, Potter
O. C. Fisher (San Angelo)	Tom Green
Palestine	Anderson, Cherokee, Henderson, Smith
Possum Kingdom	Palo Pinto, Stephens, Young
Sam Rayburn	Angelina, Jasper Nacogdoches, Sabine, San Augustine
Somerville	Burleson, Lee, Washington
E. V. Spence	Coke
Stamford	Haskell
Stillhouse Hollow	Bell
Tawakoni	Hunt, Rains, Van Zandt
Texoma	Cooke, Grayson TX; Bryan, Johnston, Love, Marshall, OK
Travis	Burnet, Travis
Trinidad	Henderson
Twin Buttes	Tom Green
White River	Crosby
Whitney	Bosque, Hill
Wright Patman (Texarkana)	Bowie, Cass


MEDINA LAKE

MEDINA LAKE

STORET NO. 4122

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Medina Lake is meso-eutrophic; i.e., moderately well supplied with nutrients and productive. Whether nutrient enrichment is beneficial or deleterious depends on the actual or potential effect on the uses of the lake. In this regard, no nuisance conditions are known to personnel of the Texas Water Quality Board and there is little or no known impairment of the designated beneficial uses of the lake.

Although it ranked sixteenth in overall trophic quality when the 39 Texas reservoirs sampled in 1974 were compared using a combination of six water quality parameters*, the lower ranking of this water body is largely due to the high median inorganic nitrogen which does not necessarily indicate trophic quality in this case because the lake is phosphorus limited. None of the other reservoirs had less but one had the same median total phosphorus, none of the others had less median dissolved orthophosphorus, all of the other reservoirs had less median inorganic nitrogen, 24 had less mean chlorophyll a, and four had greater mean Secchi disc transparency. Marked depression or depletion of hypolimnetic dissolved oxygen occurred at all sampling stations in May and August and at three of the four stations in November.

Survey limnologists did not observe macrophytes or surface concentrations of algae.

* See Appendix A.

B. Rate-Limiting Nutrient:

The algal assay results indicate Medina Lake was phosphorus limited at the time the sample was collected (11/05/74). The lake data indicate phosphorus limitation at all sampling stations and times.

C. Nutrient Controllability:

1. Point sources--During the sampling year, known point sources contributed 43.6% of the total phosphorus load to Medina Lake. The wastewater treatment plant at Bandera accounted for an estimated 39.3% of the total, and septic tanks serving lakeshore dwellings accounted for an estimated 4.3%.

The present phosphorus loading of 0.13 g/m^2/year is less than that proposed by Vollenweider (Vollenweider and Dillon, 1974) as an oligotrophic loading (see page 14). However, the lake is phosphorus limited, and any reduction in point-source loads could be considered a means of maintaining the present quality of the lake.

2. Non-point sources--Non-point sources accounted for 56.4% of the total phosphorus load. The Medina River contributed 29.7% and Red Bluff Creek contributed 3.5%. The ungaged minor tributaries and immediate drainage contributed an estimated 9.5%.

The phosphorus export rates of the Medina River and Red Bluff Creek were quite low during the sampling year (<1 kg/km^2).

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Lake Morphometry††:

1. Surface area: 22.56 kilometers²,
2. Mean depth: 13.9 meters,
3. Maximum depth: 36.3 meters,
4. Volume: 313,306 x 10^3 m^3,
5. Mean hydraulic retention time: 2.7 years (based on outflow).

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)†††	Mean flow (m^3/sec)†††
Medina River	1,027.7	3.510
Red Bluff Creek	145.8	0.310
Minor tributaries & immediate drainage -	246.0	0.670
Totals	1,619.5	4.490

2. Outlet -

Medina River	1,642.1*	3.671**

C. Precipitation***:

1. Year of sampling: 94.0 centimeters,
2. Mean annual: 70.0 centimeters,

† Table of metric conversions--Appendix B.
†† Latchford, 1974.
††† For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
* Includes area of lake.
** Outlet flow adjusted to equal sum of inlet flows minus evaporation (see page 10).
*** See Working Paper No. 175.

III. LAKE WATER QUALITY SUMMARY

Medina Lake was sampled four times in 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from a number of depths at four stations on the lake (see map, page vi). During each visit, a single depth-integrated (4.6 m to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the last visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 36.3 meters at station 1, 30.2 meters at station 2, 26.8 meters at station 3, and 14.6 meters at station 4.

The sampling results are presented in full in Appendix D and are summarized in the following table (the August nutrient samples were not properly preserved and were not analyzed).

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]

[illegible]

[illegible]

PARAMETER	RANGE	MEAN	MEDIAN
TEMP (C)	13.2 - 21.1	17.-	15.7
DISS OXY (MG/L)	6.8 - 9.8	8.4	7.-
CONDUCTIVITY (MICROMHOS)	200. - 325.	270.	275.
PH (STAND UNITS)	7.3 - 8.1	7.7	8.0
TOT ALK (MG/L)	240. - 310.	280.	150.
TOT P (MG/L)	0.009 - 0.041	0.021	0.012
DIFNO P (MG/L)	0.002 - 0.015	0.007	0.005
NO2+NO3 (MG/L)	0.020 - 0.400	0.223	0.250
AMMONIA (MG/L)	0.020 - 0.440	0.114	0.040
KJEL N (MG/L)	0.200 - 0.900	0.325	0.200
INORG N (MG/L)	0.200 - 0.720	0.342	0.300
TOTAL N (MG/L)	0.400 - 0.920	0.564	0.440
CHLOPYL A (UG/L)	1.6 - 2.7	2.1	2.1
SECCHI (METERS)	1.2 - 3.6	2.-	2.7

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
03/12/74	1. Dinobryon sp.	1,320
	2. Chroomonas sp.	543
	3. Coelastrum sp.	31
	4. Fragilaria sp.	272
	5. Cyclotella sp.	233
	Other genera	427
	Total	3,196
06/22/74	1. Microcystis (?) sp.	607
	2. Fragilaria sp.	500
	3. Coelastrum sp.	359
	4. Cyclotella sp.	193
	5. Chlorophytan filaments	166
	Other genera	663
	Total	2,508
08/15/74	1. Microcystis sp.	590
	2. Chlorophytan filaments	461
	3. Scenedesmus sp.	264
	4. Chroomonas sp.	198
	5. Cyclotella sp.	198
	Other genera	858
	Total	2,569
11/05/74	1. Cryptomonas sp.	131
	2. Aphanothece sp.	33
	3. Closterium sp.	33
	4. Dactylococcopsis sp.	33
	5. Flagellates	33
	Total	263

2. Chlorophyll A -

Sampling Date	Station Number	Chlorophyll A (ug/l)
03/12/74	1	5.8
	2	2.5
	3	2.9
	4	1.7
05/22/74	1	3.3
	2	62.6
	3	62.6
	4	40.9
08/15/74	1	6.6
	2	7.3
	3	2.4
	4	3.3
11/05/74	1	2.5
	2	1.6
	3	1.7
	4	2.7

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l:dry wt.)
Control	0.005	0.313	0.1
0.050 P	0.055	0.313	8.3
0.050 P + 1.0 N	0.055	1.313	16.8
1.0 N	0.005	1.313	0.1

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity

of Medina Lake was low at the time the sample was collected (11/05/74). Also, the significant increase in yield with the addition of phosphorus alone indicates that the lake was phosphorus limited at that time. Note that the addition of nitrogen alone resulted in a yield no greater than that of the control.

The lake data indicate phosphorus limitation as well. The mean inorganic nitrogen/orthophosphorus ratios were 40/1 or greater at all sampling stations and times, and phosphorus limitation would be expected.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Texas National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi), except for the high runoff months of April and May when two samples were collected. Sampling was begun in September, 1974, and was completed in August, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Texas District Office of the U.S. Geological Survey for the tributary sites nearest the lake. Outlet flow was adjusted to equal the sum of the inlet flows minus the yearly evaporation rate (an undetermined amount of water flows from the lake into the Edwards and Balcones fault zone, part of which is above and part is below the lake; Yost, 1976).

In this report, nutrient loads for sampled tributaries were calculated using mean annual concentrations and mean annual flows. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the mean concentrations in the West Prong, Medina River at station D-1 and the mean annual ZZ flow.

The operator of the wastewater treatment plant at Bandera did not

participate; therefore, nutrient loads were estimated at 1.134 kg P and 3.401 kg N/capita/year, and flows were estimated at 0.3785 m^3/capita/day.

A. Waste Sources:

1. Known municipal* .

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
Bandera	1,000	contact aer.	378.5	Medina River

2. Known industrial - None

* Anonymous, 1971.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr.	% of total
a. Tributaries (non-point load) -		
Medina River	855	29.7
Red Bluff Creek	100	3.5
b. Minor tributaries & immediate drainage (non-point load) -	275	9.5
c. Known municipal STP's -		
Bandera	1,135	39.3
d. Septic tanks* -	125	4.3
e. Known industrial - None	-	-
f. Direct precipitation** -	395	13.7
Total	2,885	100.0

2. Outputs -

Lake outlet - Medina River 1,160

3. Net annual P accumulation - 1,725 kg.

* Estimate based on 445 lakeshore dwellings, see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Medina River	141,040	67.5
Red Bluff Creek	19,160	9.1
b. Minor tributaries & immediate drainage (non-point load) -	16,620	8.0
c. Known municipal STP's -		
Bandera	3,400	1.6
d. Septic tanks* -	4,745	2.2
e. Known industrial - None	-	-
f. Direct precipitation** -	24,355	11.6
Total	210,420	100.0

2. Outputs -

Lake outlet - Medina River 87,290

3. Net annual N accumulation - 123,130 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Medina River	<1	116
Red Bluff Creek	<1	131

* Estimate based on 445 lakeshore dwellings, see Working Paper No. 175.
** See Working Paper No. 175.

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P Conc. (mg/l)	Mean Total N Conc. (mg/l)
Elm Creek	0.010	3.444
West Prong, Medina River	0.013	0.796

F. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	0.13	0.08	9.3	5.5

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Medina Lake:

"Dangerous" (eutrophic loading)	0.44
"Permissible" (oligotrophic loading)	0.22

V. LITERATURE REVIEWED

Anonymous, 1971. Inventory of municipal waste facilities. EPA Publ. OWP-1, vol. 6, Wash., DC.

Latchford, John B., Jr., 1974. Personal communication (lake morphometry). TX Water Qual. Bd., Austin.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

Yost, I. D., 1976. Personal communication (hydrologic budgets of Texas reservoirs). U.S. Geol. Surv., Austin.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

[illegible] DATA TO BE USED IN [illegible]

LAKE CODE	LAKE NAME	[illegible] TOTAL P	[illegible] INFO S	SEC- [illegible] SEC	[illegible] CHLOR	IS- [illegible] JD	[illegible] 2555 DAYS P
[illegible]	[illegible] LAKE	0.813	0.588	371,474	2.742	14,481	0.884
[illegible]	[illegible] LAKE	0.822	0.698	419,417	12.392	15,486	0.887
[illegible]	[illegible] [illegible]	0.616	0.[illegible]	376,412	8.825	15,888	0.887
[illegible]	[illegible] LAKE	0.134	0.158	461,625	22.782	14,888	0.892
[illegible]	[illegible] LAKE	0.827	0.188	478,375	4.887	14,481	0.887
[illegible]	LAKE [illegible]	0.836	0.258	437,625	8.686	15,888	0.812
[illegible]	[illegible] LAKE	0.855	0.878	463,333	14,884	11,481	0.81J
[illegible]	[illegible] LAKE	0.839	0.868	461,667	22,581	13,888	0.887
[illegible]	[illegible] [illegible]	0.818	0.458	384,412	2.588	14,888	0.884
[illegible]	LAKE [illegible] CITY	0.842	0.898	473,625	12,675	18,281	0.812
[illegible]	[illegible] [illegible] LAKE	0.113	0.138	475,187	19,755	14,888	0.858
[illegible]	[illegible] LAKE	0.825	0.848	478,111	15,867	9,888	0.859
[illegible]	[illegible] [illegible] LAKE	0.824	0.873	469,625	5,662	11,888	0.888
[illegible]	FT [illegible] [illegible] LAKE	0.848	0.185	474,989	6,267	9,688	0.823
[illegible]	[illegible] LITTLE [illegible] [illegible]	0.845	0.388	475,782	14,156	14,888	0.858
[illegible]	[illegible] LAKE	0.823	0.118	455,888	18,217	18,488	0.887
[illegible]	[illegible] LAKE	0.857	0.258	486,187	10,658	12,488	0.836
[illegible]	LAKE [illegible] THE PINES	0.831	0.898	468,888	12,919	15,988	0.811
[illegible]	[illegible] [illegible]	0.893	0.198	485,333	5,488	8,888	0.819
[illegible]	[illegible] LAKE	0.196	0.555	465,469	16,112	15,888	0.129
[illegible]	[illegible] [illegible] [illegible] LAKE	0.842	0.428	458,588	8,188	14,988	0.81[illegible]
[illegible]	[illegible] LAKE	0.818	0.488	483,582	12,9[illegible]	15,888	0.854
[illegible]	LAKE [illegible]	0.821	0.878	438,312	3,837	14,488	0.884
[illegible]	PALESTINE LAKE	0.838	0.148	442,625	18,619	14,698	0.838
[illegible]	[illegible] [illegible] [illegible]	0.823	0.878	419,845	9,495	15,688	0.889
[illegible]	[illegible] [illegible] [illegible]	0.894	0.148	481,888	24,675	16,286	0.811
[illegible]	[illegible] [illegible] [illegible]	0.824	0.158	438,458	9,287	15,888	0.884
[illegible]	E [illegible] SPRING [illegible]	0.836	0.998	462,583	11,775	15,888	0.884

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

| | | |

[illegible] OF LAKES WITH [illegible] VALUES [illegible] NUMBER OF LAKES WITH [illegible] VALUES)

LAKE CODE	LAKE NAME	[illegible] TOTAL P	[illegible] INORG N	[illegible] SEC	[illegible] CHLOPHA	[illegible]	[illegible] DISS ORTHO P	[illegible]
[illegible]	[illegible] LAKE	29 (11)	55 (21)	24 (9)	3 (1)	67 (25)	38 (10)	264
[illegible]	[illegible] LAKE	19 (7)	97 (37)	5 (2)	18 (7)	82 (31)	39 (14)	259
[illegible]	[illegible] LAKE [illegible]	88 (33)	37 (14)	87 (33)	92 (35)	1. (0)	51 (19)	372
[illegible]	[illegible] LAKE	32 (12)	78 (29)	37 (14)	21 (8)	63 (24)	38 (10)	253
[illegible]	[illegible] LAKE	11 (4)	51 (19)	13 (5)	16 (6)	72 (27)	13 (5)	176
[illegible]	[illegible] LAKE	39 (14)	34 (13)	61 (23)	45 (17)	17 (0)	21 (7)	217
[illegible]	[illegible] LAKE	88 (33)	21 (7)	92 (35)	82 (31)	17 (0)	34 (10)	384
[illegible]	[illegible]	8 (0)	65 (22)	11 (4)	5 (2)	92 (35)	8 (0)	269
[illegible]	[illegible] [illegible]	59 (22)	21 (7)	58 (22)	61 (23)	48 (17)	63 (22)	331
[illegible]	[illegible] [illegible]	84 (32)	61 (22)	76 (28)	89 (34)	17 (0)	63 (23)	348
[illegible]	[illegible] LAKE	63 (24)	51 (19)	79 (30)	71 (27)	17 (0)	76 (28)	357

[illegible] [illegible] [illegible] [illegible]

[illegible]	[illegible]	[illegible]	[illegible]
1	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]
16	[illegible]	[illegible]	[illegible]
17	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]
19	[illegible]	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]
21	[illegible]	[illegible]	[illegible]
22	[illegible]	[illegible]	[illegible]
23	[illegible]	[illegible]	[illegible]
24	[illegible]	[illegible]	[illegible]
25	[illegible]	[illegible]	[illegible]
26	[illegible]	[illegible]	[illegible]
27	[illegible]	[illegible]	[illegible]
28	[illegible]	[illegible]	[illegible]

LAKES RANKED BY INDEX NO.

RANK	LAKE CODE	LAKE NAME	INDEX NO.
29	[illegible]	LYNDON B JOHNSON LAKE	250
30	[illegible]	TEXOMA LAKE	237
31	[illegible]	SOMERVILLE LAKE	200
32	[illegible]	SAN ANGELO RESERVOIR	198
33	[illegible]	TEXARKANA LAKE	176
34	[illegible]	BRYAN LITTLE ELM RESERVO	173
35	[illegible]	TRINIDAD	169
36	[illegible]	BRYANS LAKE	159
37	[illegible]	CORPUS CHRISTI LAKE	155
38	[illegible]	HOUSTON LAKE	139
39	[illegible]	LIVINGSTON LAKE	91

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

APPENDIX D

PHYSICAL and CHEMICAL DATA

[illegible]

[illegible]

[illegible]
[illegible]
[illegible]
[illegible]

[illegible]
[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

| | | |

[illegible]

[illegible]

DATE	TIME	DEPTH	[illegible]	32217	97831
FROM	OF			CHLOROPHYL	INCAT LT
TO	DAY	FEET	[illegible]	A	PENING
				UG/L	PERCENT
[illegible]	11	0000	[illegible]	2.2	
	11	0006	[illegible]		
	11	0020	[illegible]		
	11	0045	[illegible]		
	11	0065	[illegible]		
	11	0096	[illegible]		
[illegible]	11	0000	[illegible]	92.6	
	11	0005	[illegible]		
	11	0020	[illegible]		
	11	0050	[illegible]		
	11	0075	[illegible]		
	11	0094	[illegible]		
[illegible]	24	0000		7.3	
	24	0033			3.0
[illegible]	24	0000	[illegible]	1.6	
	24	0005	[illegible]		
	24	0020	[illegible]		
	24	0022			1.0
	24	0040	[illegible]		
	24	0060	[illegible]		
	24	0075	[illegible]		
	24	0094	[illegible]		

[illegible]

[illegible]
[illegible]
[illegible]
[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]
29 32 25.0 088 59 05.0
[illegible] LAKE
[illegible] T.[illegible]

[illegible]
[illegible] [illegible]

DATE FROM TO	TIME OF DAY	DEPTH FEET	00061 [illegible] CFS, INST	32217 CHLOROPHYLL A UG/L	81631 INCUB L7 [illegible] [illegible]
[illegible]	14 20	0000	0.[illegible]	2.4	
	14 20	0005	[illegible]		
	14 20	0020	0.821		
	14 20	0040	0.[illegible]		
	14 20	0060	[illegible]		
[illegible]	11 25	0000	0.867	62.4	
	11 25	0005	0.[illegible]		
	11 25	0015	0.871		
	11 25	0045	0.813		
	11 25	0070	0.817		
	11 25	0090	0.[illegible]		
[illegible]	14 40	0040		2.4	
	14 40	0032			1.0
[illegible]	15 05	0000	0.811	1.7	
	15 05	0005	[illegible]		
	15 05	0020	0.823		
	15 05	0040	[illegible]		
	15 05	0060	[illegible]		
	15 05	0070	0.[illegible]		
	15 05	0083	0.814		

[illegible]

[illegible]
29 36 37.0 090 58 24.0
[illegible]
[illegible]

[illegible]
3

[illegible]
[illegible] FEET [illegible]

DATE FROM TO	TIME OF DAY	DEPTH FEET	[illegible] [illegible]	[illegible] [illegible] A [illegible]	[illegible] [illegible] [illegible] PERCENT
74/03/12	13 15	[illegible]	[illegible]	1.7	
	13 15	[illegible]	[illegible]		
	13 15	[illegible]	[illegible]		
	13 15	[illegible]	[illegible]		
	13 15	[illegible]	[illegible]		
	13 15	[illegible]	[illegible]		
74/05/23	11 45	[illegible]	[illegible]	45.9	
	11 45	[illegible]	[illegible]		
	11 45	[illegible]	[illegible]		
	11 45	[illegible]	[illegible]		
	11 45	[illegible]	[illegible]		
	11 45	[illegible]	[illegible]		
74/08/15	15 05	[illegible]		3.3	
	15 05	[illegible]			1.8
74/11/05	15 40	[illegible]	[illegible]	2.7	
	15 40	[illegible]	[illegible]		
	15 40	[illegible]	[illegible]		
	15 40	[illegible]	[illegible]		
	15 40	[illegible]	[illegible]		

APPENDIX E

TRIBUTARY DATA

[illegible]

[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	OF		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TO	DAY	FEET	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]
[illegible]

[illegible]

[illegible]

DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	OF	-	N-TOTAL	N	TOTAL	(ATM)	
TO	DAY	FEET	MG/L	MG/L	MG/L	MG/L P	MG/L P
[illegible]	12	50	1.840	0.280	0.815	0.805	0.816
[illegible]	10	10	0.940	0.450	0.325	0.805M	0.810M
[illegible]	10	30	0.780	0.290	0.814	0.805	0.810M
[illegible]	11	45	0.450	0.405	0.807M	0.804M	0.810M
[illegible]	11	50	1.640	0.190M	0.334	0.805M	0.810
[illegible]	10	35	0.360	0.180	0.804M	0.807M	0.810M
[illegible]	11	01	1.320	0.330	0.815	0.805M	0.810M
[illegible]	11	20	1.250	0.350	0.840	0.805M	0.810
[illegible]	10	40	1.250	0.460	0.825	0.805M	0.810
[illegible]	10	10	0.480	0.450	0.835	0.805	0.860
[illegible]	10	10	0.560	0.400	0.830	0.825	0.850
[illegible]	11	00	1.100	0.475	0.815	0.805M	0.816
[illegible]	11	00	0.980	0.350	0.830	0.805M	0.820
[illegible]	11	50	0.660	0.450	0.815	0.805M	0.820

[illegible]

[illegible] RETRIEVAL DATE: [illegible]

[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

DATE FROM TO	TIME OF DAY	DEPTH FEET	[illegible] [illegible] TOTAL MG/L	[illegible] TOT [illegible] N MG/L	[illegible] NITRO TOTAL MG/L	[illegible] AMIS-NIS DISS MG/L N	[illegible] AMIS-TOT MG/L -
74/09/07	13	55	0.460	0.150	1.825	1.8854	1.885<
74/10/06	11	30	0.384	0.100	1.815	1.8854	1.810>
74/11/07	11	45	0.440	0.405	0.815	0.815	0.815
74/12/07	14	25	0.600	0.440	0.824	0.816	1.816
75/01/07	12	45	7.600	0.1004	4.864	1.8854	0.110>
75/02/07	12	25	1.625	0.200	1.8004	0.8004	1.210>
75/03/27	12	14	0.950	0.350	0.810	0.8054	0.810>
75/04/09	13	16	0.575	0.440	0.825	0.8054	0.820
75/04/22	11	40	0.500	0.150	0.620	0.8054	0.810>
75/05/09	11	30	0.450	0.300	0.825	0.8054	0.810>
75/05/21	11	10	0.410	0.150	0.820	0.8054	0.810>
75/06/09	12	46	0.990	0.200	0.820	0.8054	0.110>
75/07/14	12	35	0.430	0.100	0.815	0.8054	0.810>
75/08/02	13	20	0.430	0.200	0.805	0.820	0.820

[illegible] VALUE [illegible] TO BE
LESS THAN INDICATED

[illegible]

[illegible]
29 51 38.0 083 [illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

DATE	TIME	DEPTH	00038	00625	00610	00671	00665
			[illegible]	TOT KJEL	[illegible]	PHOS-DIS	PHOS-TOT
FROM	OF		[illegible]	N	TOTAL	[illegible]	
TO	DAY	FEET	MG/L	MG/L	MG/L	MG/L P	MG/L P
75/09/07	14	10	0.142	0.480	3.047	0.005<	0.06[illegible]
75/10/06	11	30	1.144	0.190	0.015	0.005<	0.010<
75/11/07	12	00	0.366	0.480	0.016	0.005	0.010<
75/12/07	14	45	0.672	0.480	0.019	0.006<	0.010<
75/01/07	13	20	0.790	0.190	0.020	0.005<	0.010<
75/02/07	14	50	0.945	0.190<	0.020<	0.006<	0.010<
75/03/07	12	34	0.740	0.950	0.010	0.005<	0.010<
75/04/08	14	01	0.540	0.180	0.040	0.005<	0.010<
75/04/22	11	50	0.330	0.650	0.030	0.005<	0.010<
75/05/05	11	30	0.345	0.750	0.070	0.005<	0.010<
75/05/21	11	20	0.390	0.450	0.030	0.005<	0.010<
75/06/06	13	20	0.440	0.250	0.025	0.005<	0.010<
75/07/14	12	50	0.315	0.780	0.015	0.005<	0.020
75/08/02	13	05	0.210	0.700	0.025	0.005<	0.010<

< VALUE GIVEN IS OF
LESS THAN INDICATED

[illegible]

[illegible]
29 44 25.0 098 57 40.0 4
RED HAWK CREEK
48 T.5 PINE CREEK
TAMALUNA LAKE
FM [illegible] MI SE OF SPRUCE FALLS
[illegible] 41102
8000 FEET DEPTH 2,455 TO

DATE	TIME	DEPTH	00630	00625	00610	00671	00665
FROM	OF		NITRATE	TOT KJEL	NH3+NH4	PHOS-DIS	PHOS-TOT
TO	DAY	FEET	MG/L	MG/L	MG/L	ORTHO MG/L P	MG/L P
04/09/87	11	30	1.290	0.350	0.040	0.005	0.010
04/18/86	09	40	1.440	0.100K	0.010	0.005K	0.010K
04/11/87	10	35	0.660	0.250	0.025	0.009	0.010K
04/12/87	11	35	1.100L	0.300	0.004	0.009K	0.010K
05/01/87	11	45	1.240	0.200	0.050K	0.005K	0.010
05/01/87	10	10	5.200	0.100K	0.010	0.005K	0.010K
05/03/87	11	55	2.400	0.050	0.005	0.005K	0.010K
05/04/86	10	45	2.300	0.200	1.025	0.005K	0.010K
05/04/87	10	30	2.300	0.200	0.015	0.005K	0.010
05/05/86	10	00	1.700	0.300	0.045	0.005K	0.010K
05/05/21	09	55	0.810	0.400	0.020	0.005K	0.010K
05/06/86	10	45	1.650	0.350	0.010	0.005K	0.010K
05/07/04	10	50	1.150	0.050	0.010	0.005K	0.010K

K VALUE KNOWN TO BE
LESS THAN INDICATED

L ACTUAL VALUE IS KNOWN TO BE
GREATER THAN VALUE GIVEN

[illegible]

[illegible]
[illegible]
[illegible]

[illegible]

[illegible]
29 47 38.0 099 26 45.0 4
[illegible]
[illegible]
TAMAULIPAS LAKE
[illegible]
[illegible]
[illegible]

DATE	TIME	DEPTH	00630	00625	00610	00671	00665
FROM	OF		NO2&NO3	TOT KJEL	NH3-N	PHOS-DIS	PHOS-TOT
TO	DAY	FEET	MG/L	MG/L	MG/L	MG/L P	MG/L P
74/09/17	13	30	0.370	0.100	0.020	0.005K	0.005K
74/10/06	09	55	0.410	0.100K	0.020	0.005K	0.010K
74/11/07	10	40	0.410	0.700	0.030	0.010	0.010
74/12/07	09	10	0.600	0.300	0.015	0.005K	0.010K
75/01/07	12	30	0.690	0.200	0.010	0.025	0.010K
75/02/07	13	25	0.700	0.100	0.005K	0.005K	0.010K
75/03/07	13	07	0.735	0.150	0.025	0.005K	0.01C
75/04/08	12	32	0.450	0.550	0.055	0.005K	0.030
75/04/22	11	25	0.400	0.400	0.027	0.005K	0.020
75/05/06	10	55	0.260	0.375	0.020	0.005K	0.010K
75/05/21	10	55	0.410	0.455	0.030	0.005K	0.015
75/06/08	13	00	0.540	0.200	0.010	0.005K	0.010K
75/07/24	12	15	0.250	0.150	0.015	0.005K	0.020
75/08/12	11	35	0.300	0.400	0.015	0.005K	0.010K

K VALUE KNOWN TO BE
LESS THAN INDICATED